Colegio de Postgraduados

Effect of starch from chayotextle (*Sechium edule* (Jacq.) Sw.) and erythritol on the physicochemical and sensorial quality of a yogurt enriched with inulin

Gutiérrez-Tlahque, Jorge[1*]; Altamirano-Romo, Susana E.[1]; Garrido-Torres, Marcelo[3]; Vargas-Torres, Apolonio[4]; Muñoz-Sánchez, Giselle[5]

[1] Instituto Tecnológico de Roque, Departamento de Ciencias Agropecuarias, Carretera Celaya-Juventino Rosas km 8, Celaya, Guanajuato, México. C.P. 38110.
[2] Instituto Tecnológico de Roque, Departamento de Ingenierías, Carretera Celaya-Juventino Rosas km 8, Celaya, Guanajuato, México. C.P. 38110.
[3] Instituto Tecnológico de Zitácuaro, Ingeniería en Innovación Agrícola Sustentable, Av. Tecnológico Manzanillos No. 186, Zitácuaro, Michoacán México. C.P. 61534.
[4] Universidad Autónoma del Estado de Hidalgo, Instituto de Ciencias Agropecuarias, Av. Universidad km 1, Rancho Universitario, Tulancingo de Bravo, Hidalgo, México. C.P. 43600.
[5] Instituto Tecnológico de Zitácuaro, Ingeniería en Industrias Alimentarias, Av. Tecnológico Manzanillos No. 186, Zitácuaro, Michoacán México. C.P. 61534.
* Correspondence: jorge.gt@roque.tecnm.mx

ABSTRACT

Objective: To evaluate the incorporation of chayotextle (*Sechium edule*) root starch and erythritol on the physicochemical quality of a yogurt enriched with inulin.

Design/methodology/approach: The following treatments were established: T1: Erythritol 2.1%; T2: Starch 1% + Erythritol 2.1%; T3: Sugar 1.5% + Erythritol 1.05%; T4: Starch 1% + Sugar 1.5% + Erythritol 1.05%; T5: Sugar 3% and T6: Starch 1% + Sugar 3%. The variables nutritional content, pH, total soluble solids, syneresis, and sensorial quality were determined through CATA.

Results: The incorporation of chayotextle starch to yogurt favored an increase in the content of non-fatty solids and a decrease in syneresis, while the use of erythritol as sugar substitute decreased the caloric content and of non-fatty solids and increased the pH and syneresis, contrary to the use of sugar. Enrichening all the formulations with 5% of inulin favored the stability and increased the dietary fiber in all the treatments. Sensorially, the chayotextle starch combined with sugar favored a greater sensorial acceptance of the yogurt.

Limitations on study/implications: To evaluate the texture profile of the yogurt, as well as the use of other stabilizers such as potato, corn, yucca and gums like xanthan, arabic or even carboxymethyl cellulose which are commercial.

Findings/conclusions: The addition of erythritol does not substitute sugar as a sweetener from the sensorial point of view. However, nutritionally, it reduces the caloric content in 57%. Inulin favors the dietary fiber content, while the chayotextle starch together with sugar preserved the physicochemical and sensorial characteristics of yogurt.

Keywords: *Sechium edule*, chayote, prebiotics, sweeteners, lactic cultures.

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INTRODUCTION

Yogurt tends to be considered a healthy food since it provides many essential nutrients such as proteins, calcium, phosphorus, riboflavin, thiamine, vitamin

B12, folate, niacin, magnesium and zinc (Fernández *et al.*, 2017); however, some aspects of commercial yogurt can negatively affect health, because many have high amounts of added sugar, low dietary fiber, and artificial coloring (Soukoulis *et al.*, 2007). Nowadays, there is interest in using probiotics and prebiotics (Nyanzi *et al.*, 2021), to improve the nutritional quality of a fermented beverage that can be associated with a better health in general for the consumer (Barengolts *et al.*, 2019). Considering this, consumers are looking for a yogurt that reduces the consumption of added sugars to decrease the caloric content (Nekoueian and Jafarpour 2021). Alternative sweeteners such as stevia, aspartame, acesulfame K and sucralose can replace up to 100% of sugar in yogurt maintaining the flavor and the texture (Chadha *et al.*, 2022). In addition, there are other approaches that include adding prebiotics to yogurt such as inulin, since it favors the presence of soluble fiber that is not hydrolyzed in the human digestive tract and has a positive impact on texture and flavor, improving the sensorial properties of the yogurt when an optimal concentration of 2 to 7% is added (Abbasi Asl *et al.*, 2022; Żbikowska *et al.*, 2020). Sugar alcohols or polyols, also known as polyalcohols such as erythritol and isomaltose have been used as sweeteners in yogurt to reduce the calories and keep the sweetness (Grembecka, 2015). Erythritol is a sugar alcohol that is 60% to 80% sweeter than sugar, although without calories, and it is a food additive considered very safe in many countries (Boesten *et al.*, 2015). Natural coloring derived from plants and fruits are commonly used in yogurt to improve the appearance and the appeal for the consumer (Dias *et al.*, 2020). It has been shown that the pulp of blackberry fruits is rich in anthocyanins with great antioxidant power, an efficient natural coloring for yogurt that favored a pleasant violet pink color that complies with the industry standards (Merino-Peñafiel *et al.*, 2018).

The use of starches from potato (*Solanum lycopersicum*), sweet potato (*Ipomoea batata*) and yucca (*Manihot esculenta*), and modified corn starches (*Zea mays* L.), as stabilizers in yogurt improves the texture, the flavor and reduces the syneresis (Agyemang *et al.*, 2020; Saleh *et al.*, 2020). It has been reported that starches could partially or completely replace powdered skimmed milk in the yogurt, maintaining the quality while reducing the cost (Saleh *et al.*, 2020); however, the effects of the addition of starch depend on the type and amount (Skryplonek *et al.*, 2019). Among the new sources of starch, there is chayotextle root, from the *Sechium edule* plant which is native to Mexico and has been reported as a source of polysaccharides like pectins, arabigans, galactans and arabinogalactans. These polysaccharides are stable even after cooking, in addition to being a good source of starch and fiber (Shiga *et al.*, 2015).

Since there is no information about the use of chayotextle root starch as stabilizer, or about the use of erythritol as sweetener in yogurt elaboration, the incorporation of chayotextle root starch and erythritol as sweetener in a yogurt enriched with inulin was evaluated, on its physicochemical and sensorial quality.

MATERIALS AND METHODS

Collection of blackberry fruits for coloring

The blackberry fruits from the species *Rubus Fruticosus* L. were harvested in maturity for consumption in Zitácuaro, Michoacán (19° 25' 43" N and 100° 23' 25" W) at an altitude of 1940 m.a.s.l., in a Cwb climate according to Koppen and modified by García (2004).

The blackberry fruits were taken to a pressing process, so that the juice that could be obtained from this process could be subjected to reduced evaporation with a pressure of 70 mb at 40 °C in a rotary evaporator (Buchi. R100, Suiza). Lastly, the concentrated juice was stored in refrigeration at 2 °C for its later incorporation into the corresponding treatments.

Extraction of chayotextle starch

The chayotextle was harvested in Irimbo, Michoacán (19° 41' 48" N and 100° 28' 16" W), at an altitude of 2120 m.a.s.l., with Cwb climate according to Koppen and modified by García (2004), and then the starch extraction was carried out according to Román-Brito *et al.* (2020).

Elaboration of enriched yogurt

The yogurt samples were prepared according to what was described by Hashim *et al.* (2009), where each of the treatments was enriched with 5% of inulin and inoculated with starter cultures *Lactobacillus delbrueckii* subsp. bulgaricus and *Streptococcus thermophilus* at 2% (Vivolac, United States).

Physicochemical quality: bromatological analysis

The nutritional analysis of yogurt samples was carried out according to AOAC (2003). The moisture content was determined (method 934.01), lipids determined by Soxhlet extraction (method 920.39), raw protein according to method 955.04 with a conversion factor of 6.25, ash content (method 923.03), and carbohydrate content by difference. The total dietary fiber of the samples was determined with the method 962.09.

pH and Total Soluble Solids

The pH of the samples was detrmined under room temperature conditions, according to the AOAC method (2011). The content of total soluble solids was measured according to Torrico *et al.* (2019) and expressed in °Brix.

Determination of syneresis

This variable is determined according to Robitaille *et al.* (2009), where a centrifuge was used (Velab, TDL-50B, Mexico) at 2200 rpm during 10 min at 4 °C, where the susceptibility of syneresis was calculated, through the following formula:

$$Syneresis = (Weight\ of\ supernatant)/(Weight\ of\ the\ sample) \times 100$$

Sensorial analysis by the CATA test

For this sensorial test of the yogurt variations, the attributes were randomized and n=50 consumers were asked to indicate the sensorial characteristics of the yogurt through the CATA method, according to Ghasempour *et al.* (2020), where the sensorial terms were previously identified by experts of yogurt consumption.

Experimental design

For the analysis of the physicochemical variables, a completely randomized experimental design was established with a LSD means comparison test with $P \leq 0.05$, where 6 treatments were established that consisted in changing the amount of stabilizers such as chayotextle starch and sweeteners. T1: Erythritol at 2.1%; T2: Starch at 1% + Erythritol at 2.1%; T3: Sugar at 1.5% + Erythritol 1.05%; T4: Starch at 1% + Sugar at 1.5% + Erythritol at 1.05%; T5: Sugar at 3%; and T6: Starch at 1% + Sugar at 3%. In the case of the sensorial analysis, the CATA method was used where Cochran's Q test was conducted with a value of $q \leq 0.05$ and multivariate correspondence analysis. All the statistical analyses were carried out with the R Studio software version 12.0.

RESULTS AND DISCUSSION

According to Table 1, the treatment that obtained the highest moisture content was T1 where the sweetener was erythritol; contrary to this, T6 with sugar as sweetener resulted in the lowest moisture percentage, and this way the addition of sugar to yogurt increased the viscosity and the excess in air volume incorporated to the yogurt, which indicates a decrease in moisture in addition to higher amounts of sucrose, dextrose and fructose increasing the viscosity from 6 to 8% (Guggisberg *et al.*, 2011). The fat content was not significant, but lower than in other yogurts that present inulin at 7% and a yogurt with modified starches where the fat content was 2.88% and 2.40%, respectively (Iriondo-DeHond *et al.*, 2020). This indicates that the amount of fat in the yogurt depends on the type of milk used, and the addition of fat and sugar (Arriaga *et al.*, 2019). In addition, the starter cultures of yogurt can affect the levels of fat because of their lipolytic activity, especially when they are combined with different amounts of added sugar (Rodríguez-Bernal *et al.*, 2014; Aslam *et al.*, 2015). The highest caloric content is attributed to T6 and the lowest caloric content to T1, and therefore the sugar content of yogurt has a significant impact on its recount of calories and nutritional profile (Güven *et al.*, 2005). Likewise, yogurt, which has starches in its composition, significantly favors the caloric density (Miao *et al.*, 2021). The use of erythritol in yogurt resulted in the lowest percentage of glucid (9.81%), a sugar alcohol low in calories that

Table 1. Nutrition content of blackberry yogurt enriched with inulin and chayotextle starch using different sources of sweeteners.

Treatments	Moisture	Fat	Proteins	Carbohydrates	Ash	Dietary fiber	Energy (Kcal)
	%						
T1	80.29 a*	1.41 a	3.47 a	9.81 f	0.66 a	4.37 a	65.79 f
T2	72.94 d	1.55 a	3.22 a	17.40 c	0.64 a	4.25 a	96.43 c
T3	78.29 b	1.40 a	3.41 a	12.25 e	0.49 a	4.16 a	75.26 e
T6	68.26 f	1.54 a	3.64 a	21.65 a	0.62 a	4.30 a	115.00 a
T4	70.61 e	1.65 a	3.57 a	19.31 b	0.67 a	4.19 a	106.40 b
T5	75.22 c	1.70 a	3.59 a	14.62 d	0.65 a	4.24 a	88.07 d

* Values followed by different letters in the same column showed significant differences ($p \leq 0.05$) according to the LSD test. T1: Erythritol 2.1%; T2: Starch 1% + Erythritol 2.1%, T3: Sugar 1.5% + Erythritol 1.05%; T4: Starch 1% + Sugar 1.5% + Erythritol 1.05%, T5: Sugar 3%, and T6: Starch 1% + Sugar 3%.

is not metabolized by the organism, so it presents lower caloric content than sugar (Regnat *et al*., 2018).

In the case of the protein content, no statistical difference was found between the treatments. Iriondo-DeHond *et al.* (2020) mention that for yogurt enriched with 7% inulin, the protein content was 2.78% lower than this research study, and it has been shown that the addition of inulin to yogurt favors a higher protein content (Balthazar *et al*., 2016). Similarly, the dietary fiber content in the treatments did not present statistical differences between treatments, and several studies agree that adding between 1% and 5% of inulin to the yogurt increases its dietary fiber content (Żbikowska *et al*., 2020).

Table 2 shows the treatments with highest amount of soluble solids (T4, T5 and T6), which is due to the sugar and chayotextle starch, which agrees with Estévez *et al.* (2010). The starches absorb water and swell during the yogurt fermentation, increasing the total solids (Wong *et al*., 2020). Lower total soluble solids indicate lower sugar content that acts as a load agent in the sample, which is why it will be more diluted (Thun *et al*., 2022).

In the case of the pH, it was found that treatments T1, T2 and T3 presented similar values, and they were the highest values in pH, where its composition is mostly lower or no amount of sugar, and the sucrose added increases the necessary time for yogurt to reach its breakdown pH, indicating that sugar slows down the rate of lactic acid development since it makes microbial growth slower, and therefore the specific effects depend on the type and amount of sugar or starch added (Estévez *et al*., 2010).

In the gel syneresis, it was found that the formulations that presented in their composition chayotextle starch favored lower syneresis. This is because this stabilizer functions through its capacity to form gel structures in water, which leaves less water free for syneresis; that is, when starches are added, such as potato and yucca, the separation of serum in the yogurt decreases, since they form a complex with casein that gives more body and more protection against syneresis, and in addition they participate as generators of viscosity and can withstand severe processing conditions of low pH, high heat and extreme shear (Chandan *et al*., 2017). The inulin that is present in all the formulations presented prebiotic fiber that decreased the syneresis, which resulted in a lower separation of the serum (Rezaei *et al*., 2014).

Table 2. Physicochemical properties for a blackbery yogurt enriched with dietary fiber and chayotextle starch.

Treatments	Total soluble solids °Brix	pH	Synersis %
T5	5.70 a*	3.77 b	1.20 a
T6	5.53 a	3.76 b	0.59 b
T4	5.60 a	3.75 b	0.66 b
T1	4.80 b	3.83 a	1.26 a
T3	4.50 b	3.86 a	1.70 a
T2	4.80 b	3.86 a	0.23 b

*Values followed by different letters in the same column showed significant differences ($p \leq 0.05$) according to Tukey's test. T1: Erythritol 2.1%; T2: Starch 1% + Erythritol 2.1%, T3: Sugar 1.5% + Erythritol 1.05%; T4: Starch 1% + Sugar 1.5% + Erythritol 1.05%, T5: Sugar 3%, and T6: Starch 1% + Sugar 3%.

Sensorial analysis by the CATA Test

Table 3 shows the results from the CATA test (Check All That Apply) where, according to the Cochran test with a level of $q \leq 0.05$, the attributes that do not present statistically significant difference between treatments were fermented flavor and the attribute of elasticity. Treatment T6, which corresponded to adding sugar with starch, is the closest to an ideal yogurt, so the addition of sugar and starch has a great impact on the flavor and the quality, since the sensorial acceptability and palatability of the yogurt was improved when sugar was added (Schnettler *et al.*, 2010).

It is important to highlight that the fruity flavor is an important attribute in the ideal product, but none of the treatments proposed presented it. The creamy attribute was highest for treatment T6, with a value that is quite close to the ideal yogurt, and this is because when inulin and sugar are used, they favor a soft and creamy texture (Kamel *et al.*, 2021). The treatment T1 was the farthest from the ideal product because the erythritol decreases the effect of the sweet flavor and does not favor more texture (Akesowan, 2009), attributes that are highly valued in yogurt.

According to Figure 1, for the X axis, the sweet and insipid attributes determined the highest variance and therefore they are associated with the flavor; while for the second axis, the attributes that presented the greatest effect for axis Y were lumpy and firm, which are characteristics of the texture attribute. Therefore, the first two dimensions contributed 82.8% of variability of all the data. Additionally, it can be seen in this test that treatment T6 is the treatment with the most similar characteristics to the ideal yogurt (creamy, fruity, sweet and firm), except for the color, which is considered better in treatment T5, because it has been reported that when sugars such as sucrose, glucose and fructose are added, this

Table 3. Results from the sensorial analysis of Cochran's Q test after using the CATA method for a blackberry yogurt enriched with dietary fiber and chayotextle starch.

Attributs	p-value	T1	T2	T3	T4	T5	T6	Ideal
Fruity*	0.00001	0.26 a	0.26 a	0.23 a	0.23 a	0.14 a	0.20 a	0.91 b
Dairy aroma*	0.009	0.86 a	0.63 a	0.77 a	0.80 a	0.77 a	0.57 a	0.57 a
Creamy*	0.00001	0.23 a	0.46 ab	0.46 ab	0.49 abc	0.69 bc	0.86 c	0.91 c
Sweet*	0.00001	0.14 ab	0.09 a	0.31 bc	0.6 cd	0.49 bc	0.31 bc	0.86 d
Firm*	0.00001	0.03 a	0.23 bc	0.14 ab	0.14 ab	0.49 cd	0.37 bc	0.51 d
Bitter*	0.00001	0.43 b	0.29 ab	0.23 ab	0.14 ab	0.14 ab	0.28 ab	0 a
Fermented	0.13440	0.34 a	0.23 a	0.26 a	0.26 a	0.17 a	0.17 a	0.12 a
Acid taste*	0.02799	0.74 b	0.46 ab	0.48 ab	0.53 ab	0.43 ab	0.40 a	0.49 ab
Purple color *	0.00001	0.57 abc	0.26 a	0.34 ab	0.63 bc	0.75 c	0.37 ab	0.83 c
Viscous *	0.001981	0.26 a	0.66 b	0.37 ab	0.26 a	0.31 ab	0.34 ab	0.29 ab
Gelatinous*	0.00001	0.09 ab	0.40 c	0.09 ab	0.23 bc	0.06 a	0.09 ab	0.05 a
Lumpy *	0.00001	0.03 a	0.40 c	0.06 ab	0.03 a	0.09 ab	0.31 bc	0.03 a
Elastic	0.1751	0.17 a	0.40 a	0.25 a	0.31 a	0.29 a	0.17 a	0.26 a
Tasteless*	0.00001	0.29 b	0.51 c	0.31 bc	0.45 c	0.09 ab	0.06 ab	0 a

* Values followed by different letters in the same column showed significant differences ($p \leq 0.05$) according to the Cochran test. T1: Erythritol 2.1%; T2: Starch 1% + Erythritol 2.1%, T3: Sugar 1.5% + Erythritol 1.05%; T4: Starch 1% + Sugar 1.5% + Erythritol 1.05%, T5: Sugar 3%, and T6: Starch 1% + Sugar 3%.

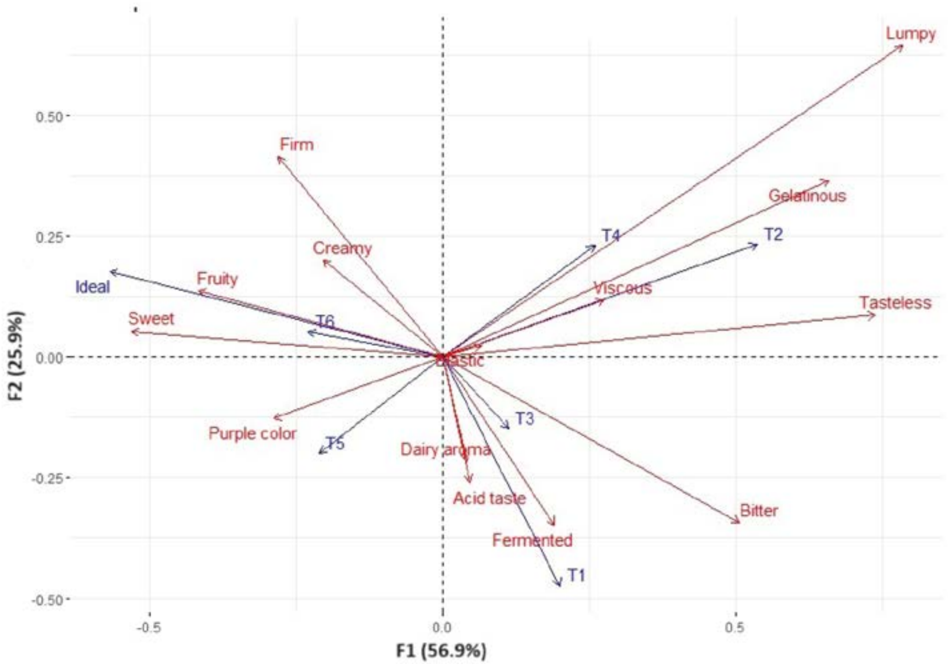

Figure 1. Correspondence analysis using the CATA test, taking into account the attributes that characterize each of the treatments evaluated and an ideal product. T1: Erythritol 2.1%; T2: Starch 1% + Erythritol 2.1%, T3: Sugar 1.5% + Erythritol 1.05%; T4: Starch 1% + Sugar 1.5% + Erythritol 1.05%, T5: Sugar 3%, and T6: Starch 1% + Sugar 3%. Source: Prepared by the authors (2023).

helped to stabilize pigments such as the anthocyanins from blackberries during processing and storage, which gave place to brighter and more vibrant colors that last (Kopjar 2012; Sadilova 2009). However, it can be observed in this study that the absence of erythritol and the addition of sugar positioned them with the highest degree of acceptance by consumers, so sweetness is a factor associated to consumer satisfaction of dairy products (McCain *et al.*, 2018). According to Oliveira *et al.* (2015), strategies are required based on the reduction of sugar depending on the perception of the sweet flavor of those that are based on product acceptance; thus, in a study with dairy desserts, a 20% sugar reduction affected the perception of sweetness through the flavor. Likewise, Andrade-Oliveira *et al.* (2021) showed that it is possible to reduce the yogurt's sweetness by 25% without compromising the perception and the acceptance. Treatments T2 and T4 were located in the quadrant with the least accepted attributes by the consumer, that is, they were described as gelatinous, insipid, lumpy, viscous and elastic; both treatments contain erythritol and starch in their formulation, which, despite being a viable option to decrease the sugar content, do not satisfy the needs of the consumer sensorially.

CONCLUSIONS

The use of chayotextle starch in yogurt had a positive impact in the content of non-fatty solids and lower syneresis; however, it favors a higher caloric content and in combination with inulin at 5%, it favored the stabilizing effect in all the treatments, increasing the dietary fiber content and resulting in higher protein level. For the use of erythritol as partial and total substitute of sugar, it decreased the caloric content in 57%; however, sensorially it was not the most accepted, and it was found that the treatment that incorporates chayotextle starch at 1% with sugar at 3% was the most accepted by consumers, where the attributes that most stood out were fruity aroma, creamy texture and sweet flavor, which agree with the attributes of a commercial yogurt.

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